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ABSTRACT

These materials, used in a self-paced course in engineering descriptive geometry for freshman and sophomore college-level students, cover three modules: basic spatial relationships; intersections, parallelism, and perpendicularity; and graphic analysis and development. Each module contains five instructional units. Each unit includes a rationale, a set of performance objectives, the evaluation criteria, and a list of assignments to be completed. The learning activities specified for each unit include viewing a slide-tape program, completing reading assignments in the text and in supplementary publications, and solving problem sets. A short introduction to each module gives an overview of topics being covered, specified the text being used, and describes the general evaluation procedures for the module. (DT)

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ENGINEERING

A Self-Paced Instructional Approach for Engineering Descriptive Geometry

The Engineering Graphics Department of the University of Wisconsin Center-Fond du Lac has developed a self-paced instructional approach for freshman and sophomore level students who are enrolled in Engineering Descriptive Geometry in an attempt to promote efficient utilization of classroom space and student time while improving the quality of the educational experience.

This self-paced approach allows students to explore the various principles of descriptive geometry through an "unconventional" instructional system that emphasizes the use of media, small group discussions, individualized study schedules and the utilization of a student who has mastered course material serving as a tutor to help others learn.

The course is divided into three one-credit modules, with each module containing five instructional units. Each unit has a clearly stated rationale, set of performance objectives, evaluation criteria, and listing of resources to facilitate student learning. A slide-tape program has been developed for each instructional unit to augment assigned readings and laboratory performance problems. After viewing the slide-tape program and completing the required readings and problem assignments for a unit, the student must demonstrate mastery of the performance objectives. Unit assessments require performance examinations and, in some instances, oral responses. If the student does not fully meet the unit objectives, the

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instructor offers counsel and, after additional study, the student may retake a similar assessment until mastery is attained. The mastery of the objectives within each unit of a module is assessed within the context of a graphic performance examination, some individual discussion, and an objective measure of information achievement administered by the instructor or proctor.

This self-paced instructional approach was used in a fifteen-student pilot class with very encouraging results, based upon the subjective views of the instructor and proctor involved and on course evaluations by students. Because of this preliminary success, the self-paced format will continue to be offered at the UW Center-Fond du Lac. The possibility of expanding this approach to teaching Descriptive Geometry to other campuses within the University of Wisconsin System is currently being explored.

For additional information, contact Dr. Eugene J. Beck, Director of Educational Services, University of Wisconsin Center-Fond du Lac, Fond du Lac, Wisconsin 54935.

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GRA-102 ELEMENTS OF DESCRIPTIVE GEOMETRY

Descriptive geometry is the science of graphic representation and solution of space problems. This course is intended to provide you with opportunities to develop:

1. the ability to visualize spacial relationships,
2. skill and techniques in the solution of engineering space problems,
3. interest in further study of the principles of descriptive geometry and its relationship to engineering graphics.

Module 1. Basic Spacial Relationships

This module focuses on the principles of orthographic and auxiliary view projection. Also introduced are simple concepts involving the solution of spacial relationships of lines and planes.

Text Material:

Engineering Graphics, by Giesecke and others, Second Edition. (Macmillan Publishing Co., Inc.) Other readings are on reserve in the library.

Evaluation:

Your mastery of the objectives within each unit of this module will be assessed within the context of a graphic performance quiz, some individual discussion, and an objective measure of informational achievement administered by the course instructor or proctor. Upon completion of the module activities and assessments, a combination graphic performance and objective multiple choice and/or true-false examination will be used to evaluate individual student performance. Items on the examination will be keyed to specific objectives in the units of this module.

Unit 1. Theory of Orthographic Projection

Rationale: From his early beginning, man has endeavored to record and communicate his ideas through the medium of visual illustrations. For a rapid representation of an idea, the pictorial type of drawing is often used. For the completeness of detail necessary in the design and construction of a machine, structure or device, the technical drawing based on the principles of orthographic projection is employed.

Your Objectives: You should be able to --

1. Explain the basic principles of orthographic projection.
2. Define the basic terminology associated with orthographic projection.
3. Differentiate between First and Third-Angle Projection.
4. Visualize and graphically represent the use of folding lines as they relate to orthographic projection.
5. Visualize and graphically represent orthographic views in a multiview drawing.
6. Accurately transfer distances in multiview drawings utilizing the folding lines.
7. Use proper notations with respect to folding lines and multiview drawings.
8. Accurately solve space problems involving orthographic projection.
9. Graphically determine the visibility of intersecting lines in principal views.
10. Graphically determine the visibility of non-intersecting lines in principal views.

Evaluation: When you feel that you can meet these unit objectives in a 25-30 minute quiz, proceed to your instructor or course proctor for an assessment. The quiz will include the solution of graphic problems as well as an objective multiple choice and/or true-false measure of informational achievement.

Learning Resources: The following resources are suggested:

1. View the slide-tape program D-1, Theory of Orthographic Projection, (available in the library).

2. Read Chapter 6 of Giesecke and others, pp. 153-172.

3. Read Chapter 1 of Pare', Loving and Hill, Descriptive Geometry (on reserve in library).

4. Solve problems on worksheets 13 and 18. Engineering Graphics Problems, Series 1, Second Ed., Spencer, Hill and Loving.

   See pp. 22 and 23 in Giesecke and others, Fig. 2.15 Alphabet of Lines. Study this page as to line usage.

5. Discuss any questions you may have or unmet objectives with your course instructor.

Unit 2. Primary Auxiliary Views

Rationale: Although the essential details of most objects can be shown in front, top and profile views, many of the more complex problems require for their solutions the use of auxiliary views. This unit will introduce their basic principles of primary auxiliary view projection on the solution of space problems.

Your Objectives: You should be able to --

1. Explain the basic principles of auxiliary view projection.
2. Define the basic terminology associated with auxiliary view projection.
3. List and identify primary auxiliary views.
4. Solve primary auxiliary view problems utilizing the folding line method.
5. Determine the visibility of primary auxiliary views.
6. Graphically solve auxiliary views projected from a top view.
7. Graphically solve auxiliary views projected from a front view.
8. Graphically solve auxiliary views projected from a side view.
9. Graphically develop the normal (true size) view of a plane with the edge view given.
10. Graphically plot a curve by projection.

Evaluation: When you feel that you can meet these unit objectives in a 25-30 minute quiz, proceed to your instructor or course proctor for an assessment. The quiz will include the solution of graphic problems as well as an objective multiple-choice and/or true-false measure of informational achievement.

Learning Resources: The following resources are suggested:

1. View the slide-tape program D-2, Primary Auxiliary Views, (available in the library).

2. Read Chapter 8 of Giesecke and others, pp. 229-235 and p. 236, 8.12.

3. Read Chapter 2 of Pare', Loving, and Hill, Descriptive Geometry (on reserve in library).

4. Solve problems on worksheets 28, 30. Engineering Graphics Problems, Series 1, Second Ed., Spencer, Hill and Loving.

5. Discuss any questions you may have or unmet objectives with your course instructor.

Unit 3. Lines

Rationale: The term line is generally used to designate a straight line unless otherwise specified. Theoretically, a line is of indefinite length, but frequently when the conditions of a problem make it obvious, the term implies a definite line segment. This unit will introduce a few simple concepts involving the solution of spacial relationships of lines.

Your Objectives: You should be able to --

1. Differentiate between the principal lines:
   - Frontal
   - Horizontal
   - Profile
2. Graphically construct the true length of a principal line and the true angle it forms with the principal planes of projection.
3. Graphically construct the true length of an oblique line and the true angle it forms with the principal planes of projection.
4. Define the bearing, slope and grade of a line.
5. Graphically solve and calculate the bearing, slope (or grade) and true length of a line.
6. Graphically develop the views of a line given its bearing, slope (or grade) and length.
7. Differentiate between intersecting and non-intersecting lines.
8. Graphically construct the views of intersecting lines.
9. Graphically construct the views of non-intersecting lines.
10. Graphically construct a point on a line in principal and successive views of the line.
11. Determine points on a line by way of spacial descriptions.

Evaluation: When you feel that you can meet these unit objectives in a 25-30 minute quiz, proceed to your instructor or course proctor for an assessment. The quiz will include the solution of graphic problems as well as an objective multiple choice and/or true-false measure of informational achievement.

Learning Resources: The following resources are suggested:

1. View the slide-tape programs D-3A, D-3B and D-3C, Lines, (available in the library).

2. Read Giesecke and others, Chapter 8, p. 240 (8.18) and Chapter 19, pp. 569-578.

3. Read Chapter 3 of Pare', Loving and Hill, Descriptive Geometry (on reserve in library).

4. Solve problems on worksheets 48, 50, 51, 52 omit problem 1, and 49; there are several answers to problems 1, 2, 3, 4, and 6 on worksheet 49. Engineering Graphics Problems, Series 1, Second Ed., Spencer, Hill and Loving.

5. Discuss any questions you may have or unmet objectives with your course instructor.

Unit 4. Planes

Rationale: A plane is a surface such that a straight line connecting any two points in that surface lies wholly within the surface. Any two lines in a plane must therefore either intersect or be parallel. The general term "plane" implies a plane surface indefinite in extent unless otherwise specified.

Your Objectives: You should be able to --

1. Define a plane.
2. Identify four ways in which planes can be represented.
3. Graphically represent a plane surface in multiview projection.
4. Graphically locate a point on a plane surface in multiview projection.
5. Graphically locate the views of a given line lying in a plane surface.
6. Graphically develop the views of a frontal line in a plane surface.
7. Graphically develop the views of a horizontal line in a plane surface.
8. Graphically develop the views of a profile line in a plane surface.
9. Define locus.
10. Apply the space analysis procedure in the location of a point in a plane surface.

Evaluation: When you feel that you can meet these unit objectives in a 25-30 minute quiz, proceed to your instructor or course proctor for an assessment. The quiz will include the solution of graphic problems as well as an objective multiple choice and/or true-false measure of informational achievement.

Learning Resources: The following resources are suggested:

1. View the slide-tape program D-4, Planes, (available in the library).

2. Read Chapter 19 of Giesecke and others, pp. 579-582.

3. Read Chapter 4 of Pare', Loving and Hill, Descriptive Geometry, (on reserve in the library).

4. Solve problems on worksheet 54 and on instructor made sheet to show a frontal, horizontal and profile line in various planes. Engineering Graphics Problems, Series 1, Second Ed., Spencer, Hill and Loving.

5. Discuss any questions you may have or unmet objectives with your course instructor.

Unit 5. Successive Auxiliary Views

Rationale: In Unit 2, you dealt with primary auxiliary views -- that is, single auxiliary views projected from one of the principal views. In this unit you will examine the development of secondary and successive auxiliary views which are used to obtain information available only in views projected on planes that are oblique to the principal planes.

Your Objectives: You should be able to --

1. Differentiate between secondary and successive auxiliary views.
2. Graphically construct the successive auxiliary views of an object.
3. Determine the visibility of successive auxiliary views.
4. Graphically construct a secondary auxiliary view of an object.
5. Graphically construct the point view of frontal, horizontal and profile lines.
6. Graphically construct the true distance from a point to a line (point-view method).
7. Graphically construct the edge view of an oblique plane surface.
8. Graphically construct the normal (true size) view of an oblique plane surface.
9. Graphically construct the point view of an oblique line.
10. Graphically construct the axis of the elliptical views of a circle in an oblique plane.

Evaluation: When you feel that you can meet these unit objectives in a 25-30 minute quiz, proceed to your instructor or course proctor for an assessment. The quiz will include the solution of graphic problems as well as an objective multiple choice and/or true-false measure of informational achievement.

Learning Resources: The following resources are suggested:

1. View the slide-tape program D-5, Successive Auxiliary Views, (available in the library).

2. Read Chapter 8 of Giesecke and others, Auxiliary Views, pp. 240-245.

3. Read Chapter 5 of Pare', Loving, and Hill, Successive Auxiliary Views (on reserve in library).

4. Solve problems on worksheets 53, 55, 56 and on instructor made worksheet to show point view of frontal, horizontal and profile lines and on instructor made worksheet showing a successive auxiliary view. Engineering Graphics Problems, Series 1, Second Ed., Spencer, Hill and Loving.

5. Discuss any questions you may have or unmet objectives with your course instructor.

GRA-102 ELEMENTS OF DESCRIPTIVE GEOMETRY

Module 2. Intersections, Parallelism and Perpendicularity

This module centers about the analysis and graphic solution of engineering space problems involving the principles of intersections, parallelism and perpendicularity. The understanding of these principles is essential in many industrial applications.

Text Material:

Engineering Graphics, by Giesecke and others (Macmillan Publishing Co., Inc.). Other readings are on reserve in the library.

Evaluation:

Your mastery of the objectives within each unit of this module will be assessed within the context of a graphic performance quiz, some individual discussion, and an objective measure of informational achievement administered by the course instructor or proctor. Upon completion of the module activities and assessments, a combination graphic performance and objective multiple choice and/or true-false examination will be used to evaluate individual student performance. Items on the examination will be keyed to specific objectives in the units of this module.

Unit 6. Piercing Points

Rationale: Unless a line lies in or is parallel to a plane, it must intersect the plane. This intersection, called a piercing point, may be within limits of the given line segment or plane, or it may be necessary to extend one or both, in which case the piercing point can be considered imaginary. This unit examines several methods of determining piercing point.

Your Objectives: You should be able to --

1. Define what is meant by piercing point.
2. Explain the procedure involved in determining the piercing point of a plane and a line utilizing the auxiliary-view (edge-view) method.
3. Graphically determine the piercing point of a plane and a line using the auxiliary-view (edge-view) method.
4. Graphically determine the piercing point of a plane and a line using an alternate procedure of the auxiliary-view (edge-view) method.
5. Explain the procedure involved in determining the piercing point of a plane and a line utilizing the cutting-plane (two-view) method.
6. Graphically determine the piercing point of a plane and a line using the cutting-plane (two-view) method.
7. Graphically determine the piercing point of a plane and a line using an alternate procedure of the cutting-plane (two-view) method.
8. Graphically determine the pictorial intersection (piercing point) of a line and plane.
9. Determine the visibility of a line intersecting a limited plane.

Evaluation: When you feel that you can meet these unit objectives in a 25-30 minute quiz, proceed to your instructor or course proctor for an assessment. The quiz will include the solution of graphic problems as well as an objective multiple choice and/or true-false measure of informational achievement.

Learning Resources: The following resources are suggested:

1. View the slide-tape program D-6, Piercing Points, (available in the library).

2. Read Chapter 19 of Giesecke and others, pp. 584-585.

3. Read Chapter 6 of Pare', Loving and Hill, Descriptive Geometry, (on reserve in the library).

4. Solve problems on worksheets 57 and 58. Engineering Graphics Problems, Series 1, Second Ed., Spencer, Hill and Loving.

5. Discuss any questions you may have or unmet objectives with your course instructor.

Unit 7. Intersection of Planes

Rationale: Any two planes either must be parallel or must intersect, even if the intersection falls beyond the limits of the planes. The intersection of two planes is a straight line common to the planes, and its position is therefore determined by any two points common to the planes. In this unit you will examine the three general methods of developing the intersections of planes.

Your Objectives: You should be able to --

1. Define the basic terminology associated with the intersection of planes.
2. Explain the procedure involved in the development of the intersection of two planes using the auxiliary-view (edge-view) method.
3. Graphically construct the intersection of two planes using the auxiliary-view (edge-view) method.
4. Explain the procedure involved in the development of the intersection of two planes using the two-view, piercing-point method.
5. Graphically construct the intersection of two planes using the two-view, piercing-point method.
6. Explain the procedure involved in the development of the intersection of two planes using the cutting-plane method.
7. Graphically construct the intersection of two planes using the cutting-plane method.
8. Explain the procedure involved in the development of the pictorial intersection of two planes.
9. Graphically construct the pictorial intersection of two planes.
10. Determine the correct visibility of the intersection of two planes.

Evaluation: When you feel that you can meet these unit objectives in a 25-30 minute quiz, proceed to your instructor or course proctor for an assessment. The quiz will include the solution of graphic problems as well as an oral assessment.

Learning Resources: The following resources are suggested:

1. View the slide-tape program D-7, Intersection of Planes, (available in the library).

2. Read Chapter 19 of Giesecke, pp. 585-588.

3. Read Chapter 7 of Pare', Loving and Hill, Descriptive Geometry, (on reserve in library).

4. Solve problems on worksheet 59. Engineering Graphics Problems, Series 1, Second Ed., Spencer, Hill and Loving.

5. Discuss any questions you may have or unmet objectives with your course instructor.

Unit 8. Angles Between Planes/Line and Oblique Plane

Rationale: In this unit, you will be exposed to the methods used in determining the angle formed by two intersecting planes and the angle formed by a line and an oblique plane. The determination of these angles is essential in many industrial applications.

Your Objectives: You should be able to --

1. Define dihedral angle.
2. Define dip angle.
3. Define complementary angle.
4. Graphically determine the dihedral angle when the line of intersection of two planes is given.
5. Graphically determine the dihedral angle when the line of intersection of two planes is not given.
6. Graphically determine the angle between an oblique plane and a principal plane.
7. Graphically determine the angle between a line and a plane using the plane method.
8. Graphically determine the angle between a line and a plane using the line method.
9. Graphically determine the angle between a line and a plane using the complementary angle method.
10. Determine the correct visibility between lines and planes and the intersection of planes.

Evaluation: When you feel that you can meet these unit objectives in a 25-30 minute quiz, proceed to your instructor or course proctor for an assessment. The quiz will include the solution of graphic problems as well as an objective multiple choice and/or true-false measure of informational achievement.

Learning Resources: The following resources are suggested:

1. View the slide-tape program D-8, Angles Between Planes and Lines and Oblique Planes, (available in the library).

2. Read Chapter 19 of Giesecke and others, p. 588 (19.14) and Chapter 8, p. 236 (8.11).

3. Read Chapter 8 and 11 of Pare', Loving and Hill, Descriptive Geometry, (on reserve in the library).

4. Solve problems on worksheets 60, 61 and two instructor made worksheets, one showing dip and one showing the angle between an oblique plane and a principal plane. Engineering Graphics Problems, Series 1, Second Ed., Spencer, Hill and Loving.

5. Discuss any questions you may have or unmet objectives with your course instructor.

Unit 9. Parallelism

Rationale: Parallelism of lines is a property that is preserved in orthographic projections. Therefore, lines that are parallel in space project as parallel lines in any view except in those views in which they coincide or appear as points, situations that do not alter the fact that the lines are parallel. In this unit you will examine the principles of parallel lines and planes.

Your Objectives: You should be able to --

1. Define skew lines.
2. Graphically check the parallelism of principal lines.
3. Graphically check the parallelism of oblique lines.
4. Determine the true distance between two parallel lines.
5. Graphically construct a line parallel to a principal plane of projection.
6. Graphically construct parallel lines within a plane.
7. Graphically check the parallelism of planes using the edge-view method.
8. Graphically check the parallelism of planes using intersecting lines.
9. Graphically construct a line parallel to a plane.
10. Graphically construct a plane parallel to a line.
11. Graphically construct a plane through one of two skew lines and parallel to the other.
12. Graphically construct a plane through a given point and parallel to two skew lines.

Evaluation: When you feel that you can meet these unit objectives in a 25-30 minute quiz, proceed to your instructor or course proctor for an assessment. The quiz will include the solution of graphic problems as well as an objective multiple choice and/or true-false measure of informational achievement.

Learning Resources: The following resources are suggested:

1. View the slide-tape program D-9, Parallelism, (available in the library).

2. Read Chapter 20 of Giesecke and others, pp. 603-606.

3. Read Chapter 9 of Pare', Loving and Hill, Descriptive Geometry, (on reserve in the library).

4. Solve problems on worksheets 62, 63. Engineering Graphics Problems, Series 1, Second Ed., Spencer, Hill and Loving.

5. Discuss any questions you may have or unmet objectives with your course instructor.

Unit 10. Perpendicularity

Rationale: If a line is perpendicular to a plane, it is perpendicular to every line in the plane, but perpendicular lines are not necessarily intersecting lines; that is, they do not necessarily lie in the same plane. This unit examines the principles of perpendicularity with practical applications in mining and civil engineering.

Your Objectives: You should be able to --

1. Graphically check the perpendicularity of intersecting lines.
2. Graphically check the perpendicularity of non-intersecting lines.
3. Graphically construct a plane perpendicular to a line using the:
   - -- two-view or given-view method
   - -- auxiliary-view method
4. Graphically construct a line perpendicular to a plane using the:
   - -- two-view or given-view method
   - -- auxiliary-view method
5. Graphically construct a common perpendicular between two skew lines using the:
   - -- point-view method
   - -- plane method
6. Graphically check the perpendicularity of two planes.
7. Graphically construct the shortest horizontal line connecting two skew lines.
8. Graphically construct the shortest line at a specified grade connecting two skew lines.
9. Graphically project a line on a plane using the:
   - -- two-view method
   - -- auxiliary-view method

10. Define the basic terminology associated with mining and civil engineering problems.

11. Graphically construct a contour map using a grid survey.

12. Graphically solve problems involving strike, dip, thickness and outcrop.

13. Graphically solve problems involving the location of outlines of earth fills or cuts.

Evaluation: When you feel that you can meet these unit objectives in a 25-30 minute quiz, proceed to your instructor or course proctor for an assessment. The quiz will include the solution of graphic problems as well as an objective multiple choice and/or true-false measure of informational achievement.

Learning Resources: The following resources are suggested:

1. View the slide-tape program D-10A and D-10B, Perpendicularity, (available in the library).

2. Read Chapter 20 of Giesecke and others, pp. 606-614.

3. Read Chapters 10 and 12 of Pare', Loving and Hill, Descriptive Geometry, (on reserve in the library).

4. Solve problems on worksheets 64, 65, 66, 67, 78, 79, and 80. Engineering Graphics Problems, Series 1, Second Ed., Spencer, Hill and Loving.

5. Discuss any questions you may have or unmet objectives with your course instructor.

GRA-102 ELEMENTS OF DESCRIPTIVE GEOMETRY

Module 3. Graphic Analysis and Development

This, the third and last module of GRA-102, examines a variety of graphical methods utilized in the solution of numerous engineering, industrial and scientific problems. Areas covered include: revolution, vector analysis, intersections of planes and solids and developments.

Text Material:

Engineering Graphics, by Giesecke and others (Macmillan Publishing Co., Inc.). Other readings are on reserve in the library.

Evaluation:

Your mastery of the objectives within each unit of this module will be assessed within the context of a graphic performance quiz, some individual discussion, and an objective measure of informational achievement administered by the course instructor or proctor. Upon completion of the module activities and assessments, a combination graphic performance and objective multiple choice and/or true-false examination will be used to evaluate individual student performance. Items on the examination will be keyed to specific objectives in the units of this module.

Unit 11. Revolution

Rationale: Drawing-board problems are usually solved by the addition of principal or auxiliary views, usually referred to as the change-of-position method. It is also possible to revolve the object to whatever position results in a new or altered view showing the desired information. This revolution method frequently requires less construction and less working space on the drawing. In this unit, you will examine the basic principles of revolution.

Your Objectives: You should be able to --

1. Differentiate between auxiliary view projection and revolution.
2. Graphically revolve a point about its axis.
3. Graphically revolve a line about its axis.
4. Graphically develop the true length of a line by revolution.
5. Graphically develop the true length of a line and the angle it forms with a principal plane by revolution.
6. Graphically determine the angle between a line and oblique plane by revolution.
7. Graphically determine the normal (true size) view of a plane by revolution.
8. Differentiate between primary and successive revolution; be able to graphically depict each type of revolution.
9. Explain counterrevolution.
10. Graphically establish the views of a line at given angles with two principal planes by revolution.

Evaluation: When you feel that you can meet these unit objectives in a 25-30 minute quiz, proceed to your instructor or course proctor for an assessment. The quiz will include the solution of graphic problems as well as an objective multiple choice and/or true-false measure of informational achievement.

Learning Resources: The following resources are suggested:

1. Read Chapter 9 of Giesecke and others.

2. Read Chapter 13 of Pare', Loving and Hill, Descriptive Geometry, (on reserve in the library).

3. Solve problems on worksheet 33. Engineering Graphics Problems, Series 1, Second Ed., Spencer, Hill and Loving.

4. Discuss any questions you may have or unmet objectives with your course instructor.

Unit 12. Graphical Vector Analysis

Rationale: Many engineering and scientific data are graphical in nature, therefore, graphical methods utilizing such data can provide comparable accuracy for analysis of forces, velocities, accelerations and other directional quantities in structural and machine design, mechanics and other physical sciences. This unit presents some of the more common graphical solutions of problems involving vectors.

Your Objectives: You should be able to --

1. Define the basic terms associated with vector analysis.
2. Correctly apply vector notations graphically.
3. Define Bow's notation.
4. Differentiate between concurrent and non-concurrent vectors.
5. Graphically determine the resultant of concurrent coplanar vectors using the parallelogram method.
6. Graphically determine the resolution of a vector into concurrent coplanar components using the:
   - -- parallelogram method
   - -- vector-polygon method
7. Graphically determine the resultant of concurrent noncoplanar vectors using the:
   - -- plane method
   - -- parallelepiped method
   - -- vector-polygon method
8. Graphically determine the resolution of a vector into concurrent noncoplanar components using the:
   - -- parallelepiped method
   - -- edge-view method
9. Graphically determine the sum of velocity vectors.
10. Graphically determine the relative motion of two objects.

Evaluation: When you feel that you can meet these unit objectives in a 25-30 minute quiz, proceed to your instructor or course proctor for an assessment. The quiz will include the solution of graphic problems as well as an objective multiple choice and/or true-false measure of informational achievement.

Learning Resources: The following resources are suggested:

1. View the slide-tape program D-12, Graphical Vector Analysis, (available in the library).

2. Read Chapter 25 of Giesecke and others.

3. Read Chapter 14 of Pare', Loving and Hill, Descriptive Geometry, (on reserve in the library).

4. Solve problems on worksheets 84 and 86. Engineering Graphics Problems Series 1, Second Ed., Spencer, Hill and Loving.

5. Discuss any questions you may have or unmet objectives with your course instructor.

Unit 13. Intersections of Planes with Solids

Rationale: The principles involved in intersections of planes and solids have their practical application in the cutting of openings in roof surfaces for flues and stacks or in wall surfaces for pipes, etc., and in the building of sheet-metal structures. In this unit, you will determine the views of the intersection of a plane and the more common geometric solids.

Your Objectives: You should be able to --

1. Define the basic terminology associated with surfaces and solids.
2. Graphically determine the intersection of a plane and a pyramid.
3. Graphically determine the intersection of a plane and a prism.
4. Graphically determine the intersection of a plane and a right-circular cylinder.
5. Graphically determine the intersection of a plane and an inclined cylinder.
6. Graphically determine the intersection of a plane and an oblique cylinder.
7. Graphically determine the intersection of a plane and a right circular cone.
8. Graphically determine the intersection of a plane and an oblique cone.
9. Graphically represent fair surfaces.
10. Graphically determine the intersection of windshield and aircraft fuselage.
11. Graphically determine the pictorial intersection of a plane and cylinder.

EVALUATION: When you feel that you can meet these unit objectives in a 25-30 minute quiz, proceed to your instructor or course proctor for an assessment. The quiz will include the solution of graphic problems as well as an objective multiple choice and/or true-false measure of informational achievement.

Learning Resources: The following resources are suggested:

1. View the slide-tape program D-13, Intersections of Planes with Solids, (available in the library).

2. Read Chapter 21 of Giesecke and others, pp. 619-625.

3. Read Chapter 16 of Pare', Loving and Hill, Descriptive Geometry, (on reserve in the library).

4. Solve problems on worksheets 68 and 69. Engineering Graphics Problems, Series 1, Second Ed., Spencer, Hill and Loving.

5. Discuss any questions you may have or unmet objectives with your course instructor.

Unit 14. Intersections of Solids

Rationale: A machine part or structure of any kind may be assumed to consist of a number of geometric shapes arranged to produce the desired form. When a form is constructed of sheet metal or other fabricated or bonded material, an accurate representation of the intersecting surfaces becomes important, since the component parts must fit accurately and smoothly for optimum functioning and appearance. Here, the principles examined in unit 12 will be applied to the more intricate problems resulting from the intersection of solids.

Your Objectives: You should be able to --

1. Explain the basic principles involved in intersections of solids.
2. Graphically determine the intersection of two prisms.
3. Graphically determine the intersection of a prism and a pyramid.
4. Graphically determine the intersection of a prism and a cone.
5. Graphically determine the intersection of right circular cylinders.
6. Graphically determine the intersections of circular cylinders and cones.
7. Graphically determine the intersection of solids using the sphere method.
8. Graphically determine the following intersections of oblique cones and cylinders using the cutting plane method:
   - -- oblique cone and cylinder, (bases parallel and non-parallel)
   - -- two oblique cones, (bases parallel and non-parallel)
   - -- two oblique cylinders, (bases parallel and non-parallel)
9. Graphically determine the visibility of the lines of intersection of two solids.

Evaluation: When you feel that you can meet these unit objectives in a 25-30 minute quiz, proceed to your instructor or course proctor for an assessment. The quiz will include the solution of graphic problems as well as an objective multiple choice and/or true-false measure of informational achievement.

Learning Resources: The following resources are suggested:

1. View the slide-tape program D-14, Intersections of Solids, (available in the library).

2. Read Chapter 21 of Giesecke and others, pp. 625-636.

3. Read Chapter 18 of Pare', Loving and Hill, Descriptive Geometry, (on reserve in the library).

4. Solve problems on worksheets 70 and 72. Engineering Graphics Problems, Series 1, Second Ed., Spencer, Hill and Loving.

5. Discuss any questions you may have or unmet objectives with your course instructor.

Unit 15. Developments

Rationale: The development of a surface is the unfolding or unrolling of the surface of a form to coincide with a plane. The resulting plane figure gives the true size of each area of the form, so connected that when it is folded or fabricated the desired form is obtained. Practical applications of developments occur in sheet-metal work, stone cutting and pattern making.

Your Objectives: You should be able to --

1. Classify the three general groups of developments according to type of surface involved.

2. Classify the three general groups of developments according to method employed to construct the development. Explain each method.

3. Define bend allowance.

4. Graphically construct the following surfaces using the parallel line method of development:

   -- right prism
   -- oblique prism
   -- two prisms oblique to each other
   -- right-circular cylinder
   -- oblique circular cylinders

5. Define Vertex.

6. Graphically construct the following surfaces using the radial line method of development:

   -- right pyramid
   -- oblique pyramid
   -- right circular cone
   -- oblique cone

7. Define transition piece.

8. Explain the purpose of true-length diagrams.

9. Graphically construct the following surfaces using the triangulation method of development:

-- transition piece-connecting two rectangular ducts
-- transition piece-connecting two circular ducts
-- transition piece-square to round
-- transition piece-rectangular to round
-- transition piece-warped

10. Differentiate between the gore method and polyconic or zone method of developing the surface of a sphere.

Evaluation: When you feel that you can meet these unit objectives in a 25-30 minute quiz, proceed to your instructor or course proctor for an assessment. The quiz will include the solution of graphic problems as well as objective multiple choice and/or true-false measure of informational achievement.

Learning Resources: The following resources are suggested:

1. View the slide-tape program D-15, Developments, (available in the library).
2. Read Chapter 22 of Giesecke and others.
3. Read Chapter 17 of Pare', Loving and Hill, Descriptive Geometry, (on reserve in the library).
4. Solve problems on worksheets 73 and 74. Engineering Graphics Problems, Series 1, Second Ed., Spencer, Hill and Loving.
5. Discuss any questions you may have or unmet objectives with your course instructor.